DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150712

DEVELOPMENT AND FABRICATION OF A CONCENTRATING SOLAR COLLECTOR SUBSYSTEM (Second Quarterly Report)

Prepared by

Northrup, Inc.
302 Nichols Drive
Hutchins, Texas 75141

Under Contract NAS8-32251 with

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For U.S. Dept of Energy

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15. SUPPLEMENTARY NOTES

This work was done under the technical management of Mr. John Caudle, George C. Marshall Space Flight Center, Alabama.

16. ABSTRACT

This report covers the progress of work from January 1, 1977, through March 31, 1977, including work on the evacuated receiver, lens design, lens die fabrication, and improvements on components, production techniques, and performance testing.

Cost information has been removed.

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CONTENTS

I. SUMMARY

This second Quarterly Report summarizes the progress of work in all areas, and in particular, on the evacuated receiver, lens design, lens die fabrication, and improvements on components, production techniques, and performance testing.

All modifications from MSFC are acknowledged and a review of the contract, as it now stands, is given.

Significant project developments are reported, and supporting documents and data are brought up to date and discussed.

Shown below is a photograph of an evacuated receiver in the Northrup model shop.

Based on the tasks accomplished to date, a forecast of activities and the probable sequence of events is given to establish the plan for the timely completion of the project.

II. CONTRACT

The precise status of all technical tasks is given in section III of this report. The status of the contractual work is shown in the following sections. The contract is roughly 60% complete. Baseline conditions in component and system performance are on the way to being met or exceeded.

A. Changes

During the past quarter of the contract, Mr. Carl Taylor has replaced Mr. C.P. McMurray as AP32, NAS8-32251.

Modifications #1-4 have been received, acknowledged, and included in the contract.

B. Value of Work Scheduled

The extent of the work performed is summarized on the development plan schedule given in section III. Descriptions of the technical progress of each phase of the work appears in section IV. Most of the costs in the fabrication of the concentrating element, and receiver have been incurred. Major expenditures that remain are these:

1. Continued embellishments on the new attitude controller.
2. Manifold element fabrication.
3. Tests of the new lens and new receiver together.
4. Cost reduction and performance improvement of all components and installation procedures.

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DEVELOPMENT PLA
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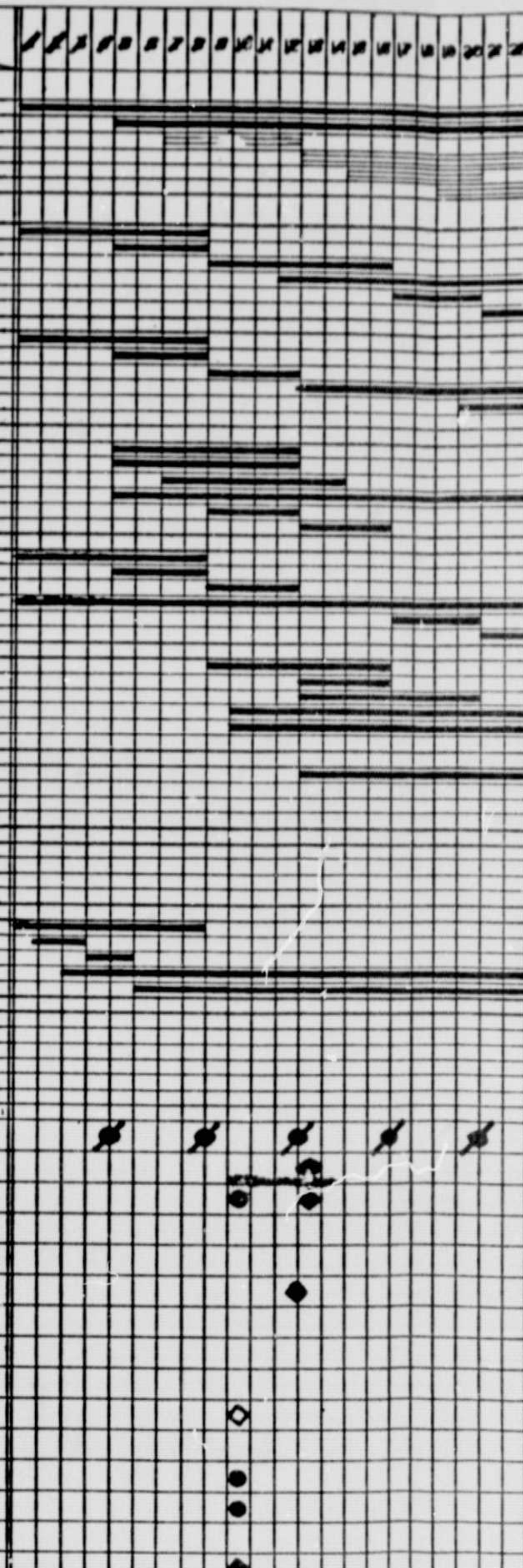
CURRENT STATUS MONITORING		WEEK [illegible]	
LATE (WEEKS)	ON SCHEDULE	AHEAD (WEEKS)	ACTIVITY
			A. LENS
	/		A. 1. DESIGN & DRAWINGS
	/		A. 2. TOOLING
	/		A. 3. FABRICATION
5			A. 4. TEST. & EVALUATION
			A. 5. REDESIGN
			A. 6. RETOOLING
			B. EVACUATED TUBE; SEAL; ABSORBER PIPE
	/		B. 1. DESIGN & DRAWINGS
		4	B. 2. TOOLING
	/		B. 3. FABRICATION
	/		B. 4. TEST & EVALUATION
			B. 5. REDESIGN
			B. 6. RETOOLING
			C. COLLECTOR HOUSING
	/		C. 1. DESIGN & DRAWINGS
	/		C. 2. TOOLING
	/		C. 3. FABRICATION
	/		C. 4. TEST. & EVALUATION
	/		C. 5. REDESIGN
	/		C. 6. RETOOLING
			D. TRACKING DEVICE HARDWARE
	/		D. 1. DESIGN & DRAWINGS
	/		D. 2. TOOLING
	/		D. 3. FABRICATION
2			D. 4. TEST. & EVALUATION
	/		D. 5. REDESIGN
			D. 6 RETOOLING
			E. TRACKING DEVICE - ELECTRONIC CONTROL
	/		E. 1. DESIGN & DRAWINGS
	/		E. 2. TOOLING
	/		E. 3. FABRICATION
		1	E. 4. TEST. & EVALUATION
	/		E. 5. REDESIGN
	/		E. 6. RETOOLING
			F. COLLECTOR ARRAY MOUNT
	/		F. 1. DESIGN & DRAWINGS
	/		F. 2. TOOLING
		1	F. 3. FABRICATION
	/		F. 4. TEST & EVALUATION
	/		F. 5. REDESIGN
			F. 6. RETOOLING
			G. SUBSYSTEM INTEGRATION
		5	G. 1. DESIGN & DRAWINGS
5			G. 2. ASSEMBLY
	/		G. 3. TESTING & EVALUATION
	/		G. 4. REDESIGN
			H. PROTOTYPES
			H. 1. ASSEMBLY
			H. 2. TESTING
			H. 3. REDESIGN
			H. 4. PROTOTYPE, FINAL ASSEMBLY TESTING & DEL.
			I. TEST FACILITY
	/		I. 1. ENGINEERING DESIGN
	/		I. 2. POURING FOUNDATION
	/		I. 3. FENCING
	/		I. 4. PROCESSING EQUIPMENT
	/		I. 5. INSTALLATION & CALIBRATION
			J. MERCHANDISING PACKAGE
			J. 1. ENGINEERING PARAMETERS INPUT
			J. 2. TEXT
			J. 3. DRAWINGS
			J. 4. DRAFT REVIEW
			J. 5. PROOFS
			J. 6. FINAL ISSUE
			FINAL ASSEMBLY, TESTING & DELIVERY
			MONTHLY STATUS REPORT
			QUARTERLY REVIEW
			DESIGN REVIEW
			ARTICLE REVIEW
			HARDWARE REVIEW
			QUALITY ASSURANCE PLAN
			ACCEPTANCE DATA PACKAGE
			QUALIFICATION & ACCEPTANCE TEST PROCEDURES
			QUALIFICATION TEST & ANALYSIS REPORT
			SPECIAL HANDLING, INSTALLATION & MAINTENANCE TOOLS LIST
			SPARE PARTS LIST
			INSTALLATION, OPERATION & MAINTENANCE MANUALS
			SUBSYSTEM HAZARD ANALYSIS
			DESIGN DATA BROCHURE
			NONCONFORMANCE REPORT AS REQUIRED



◇ LIST ● DRAWINGS
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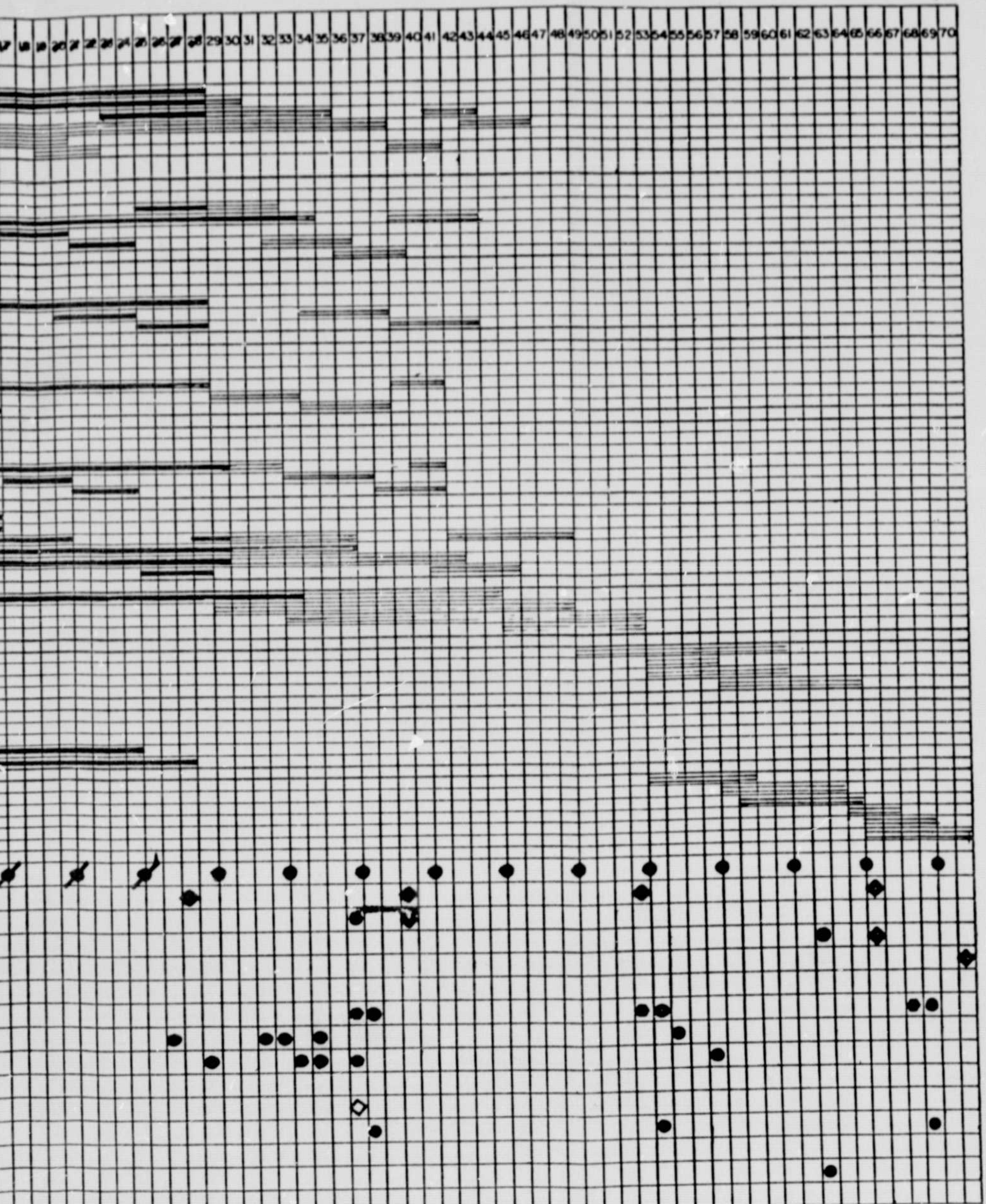

III. SCHEDULES

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A. The development plan schedule is given on Figure 2. as indicated in figure's 1 and 2, the project is behind schedule in the evaluation of the lens described in the last quarterly report. Most of the fundamental design work has been accomplished. Before completion of the contract, much testing and design improvements remain to be done.

B. The status report of the verification plan is as follows:

VERIFICATION PLAN

Performance Requirement

1. Initial design of the system is comprised of the key elements that are set forth in the development plan schedule and are referred to in part four of this report.

1.2.4 Operational Impairment . At this point in time we can only go on the knowledge based on what we know about the existing system; the comparison by similarity is that this criteria will be met in the same fashion as it was met in the initial system .

1.3 Collector Performance. As stated in the contract this requirement will be met according to the subsystem performance specification.

1.31 Collector Efficiency. The performance of the proposed collector, the subject of this project, is already expected to exceed the performance of our existing collector. The test on the receiver tube and the expected results of the new lens will bear this out.

2.1 System Design Conditions. As already determined in the existing system the new sub-system will function at the designed

flow rates, pressures and temperatures intended.

2.11 Equipment Capabilities. The forced circulation system now employeed in all existing systems will be used in this system and will be checked according to NBS standards.

2.1.2 Noise or Erosion - Corrosion. The working velocities will not exceed those recommended by Interium Performance Criteria.

2.1.3 Operating Conditions. The receiver is being designed to operate under normal operating pressures and temperature ranges that are anticipated in actual service.

2.1.4 Fluid Flow and Collectors. The manifolding of the collectors will be essentially the same as that system currently used.

2.1.5 Entrapped Air. This problem will be addressed in the prototype stage.

2.1.6 Thermal Expansion of Fluids. Expansion compensators will be used in all manifolds.

2.1.7 Pressure Drop. This will be addressed in the prototype fabrication stage.

2.1.8 Condensate. Not applicable

2.2 Machanical Stresses. This will be addressed in later stages of the development.

2.2.1 Vibration Stress Levels. Each component of the system will be analyzed by the quality control department and engineering department to reduce possibility of premature fatigue.

2.2.2 Vibration from Moving Parts. The tracking motor will be mounted to avoid unnecessary vibration. It should be noted that the tracking motor is a very fractional horsepower motor and this problem is not anticipated.

2.2.5 Thermal Changes. The thermal changes the expansion

and contraction in all components have been analyzed and are considered in the design.

2.3 Leakage Prevention. This task will be addressed later on in the design phases and in the evaluation stage of the development.

2.3.1 Pressure Tests Non Potable Fluids. The codes that are now being met by the existing collectors will be met accordingly by the proposed collector, the subject of this project,.

2.3.2. Pressure Test Potable Water. All applicable codes will be met.

2.4. Collector Adjustments. The collectors are built on an adjustable frame that can be assembled in any possible configuration necessary to receive the maximum amount of incoming solar radiation.

2.4.1 Orientation in Tilt. All collector arrays are capable if specified for seasonal adjustment to be accomplished.

2.4.2 Mutual Shadowing. This problem is taken care of in the actual layout phase of the systems. It is anticipated that there will be some shadowing in the early morning hours and the late evening hours by the collectors themselves. This problem can be minimized by judicious spacing of each tracking module.

2.7.1 Applicable Plumbing Standards. All applicable plumbing standards will be met or exceeded accordingly.

2.8 Excessive Pressure and Temperature Protection. As delineated in Section 4 of this report it is anticipated that a tracking option will be included in the additive controller to cause the collectors to go off focus when excessive pressures or temperatures occur in the system.

2.8.1 Relief Valves and Vents. Not applicable.

3.1 Structural Design basis. The structural design of each

arraywill be in accordance with general accepted codes and principles.

3.1.1. Applicable Standards. The structural design and construction of the modules will comply with the previsions mentioned.

3.1.2 Service Loads. All load conditions will be mentioned in the final delivery package.

3.2 Failure Loads and Load Capacity. Ultimate loads will be specified in the aceptance package.

3.2.1 Ultimate Load Combinations. This also will be addressed in the acceptance package.

3.2.2 Ice Loads. Actual test performed during recent 6" snow and ice fall at the Northrup facilities indicated that the existing collector can perform under severe snow and ice loading.

3.2.3 Not applicable

3.2.4 Load Capacity. All components will be checked for compliance with this performance requirement.

3.3 Damage Control. On going improvements of each component will insure compliance with this performance reqirement.

3.3.1 Resistance to Damage. The performance of this system under service load conditions is guarenteed for a period of 18 months and will be addressed in the qualification phase.

3.3.2 Glazing Design. The tensile strength of the acrylic lens is 10 times that of glass.

3.4 Cyclic Loads. Structural failures have not been a problem in the existing system.

3.4.1 Deflection Limitations. After over two years in operation no problems have been encountered in the existing system.

3.7 Hail resistance. Resistance to impact by hail has been proven by actual observation.

3.7.1 Hail Size and Loading. hail stones up to one inch in diameter have been observed and have had no effect on the existing system.

3.8 Constraint Loads.. This criteria will be met during the qualifications phase.

3.8.1 Foundation Settlement. Not Applicable

3.9.1 Design Provisions. The effect of ponding on these collectors is negligable however the qualification phase will address this problem.

4.1 Plumbing and Electrical Installation. After installing over 10,000 similar systems it is anticipated that this problem will addressed during the acceptance phase of this project.

4.1.1 Plumbing Codes and Standards. The current system is suitable for several plumbing codes and standards.

4.1.2 Electrical Codes and Standards. The current system has met all electrical codes and standards in over 100 installation sites.

4.2 Fail-Safe Controls. A power failure will effectively shut down the system.

4.2.1 System Failure Prevention. In the event of a power failure the system will shut down. The collectors will off-focus and temperatures and pressures will drop.

4.2.2 Automatic Pressure Relief Valves. Automatic Pressure relief valves are supplied with all systems.

4.3 Fire Safety. No problems are anticipated in this area.

4.3.1 Applicable fire Standards. Potential fire hazards will be addressed during the acceptance phase of the project.

4.4 Toxic and Flammable Fluids. The subsystem will not expose personnel to an undue amount of toxic and flammable fluids.

4.5.2 Identification and Location of Controls. The identification and location of controls is clearly marked on all tracking boxes.

4.6 Protection of Potable Water and Circulated Air. No material, form of construction, fixture, or item of equipment is used that would support the growth of micro-organisms or introduce toxic substances into potable water.

4.6.1 Contamination by Materials. No materials will be used that will effect potable water adversely.

4.7 Excessive Surface Temperatures. Temperatures in excess of 150° are not anticipated.

4.7.1 Protection from heated Components. Heated components will be insulated.

5.1 Effects of External Environment. Effects of external environment will be shielded as effectively as possible.

5.1.1 Solar Degradation. The solar degradation of all components will be checked during the qualification phase.

5.1.3 Airborne Pollutants. The only problems encountered in the present system have been problems with salt dew salt spray corrective action has been taken and no significant problems from airborne pollutants is anticipated for the proposed new system.

5.1.4 Dirt Retention on Cover Plate Surface. As indicated in the Pendleton Report on the original proposal for this contract dust accumulation on the lens is not been a major problem.

5.1.5 Abrasive Wear. As indicated elsewhere during this contract this has not been a problem.

5.1.6 Fluttering by Wind. Not a problem in the existing system.

5.2 Temperature and Pressure Resistance. This system is guaranteed for 18 months.

5.2.1 Thermal Degradation. Thermal degradation has not been a problem in the existing system.

5.2.2 Deterioration of Heat Transfer Fluids. Has not been addressed by this report or this project.

5.2.3 Thermal Cycling Stresses. To be addressed later in the project.

5.2.4 Leakage. The improvement of the existing swivel will be the only task to be performed in this project necessary to avoid leakage problems.

5.2.5 Deterioration of Gaskets and Sealants. This will be addressed in the design of the swivel and or bearing supports.

5.2.6 Transmission losses due to Outgassing. This was addressed in the monthly report #6 and is also addressed in section 4 of this report.

5.3 Chemical Compatibility of Components. Further checks on this we made during the qualification phase of this project.

5.3.1 Materials/Transfer Fluid Compatibility. No problems have been encountered to date along these lines.

5.3.2 Corrosion of Dissimilar Materials. Dissimilar Materials will be avoided at all cost in the design phase of this project.

5.3.4 Effects of Decomposition Products. This requirement will be addressed during the qualification phase of the project.

5.4 Components Involving Moving Parts. Much experience has been gained during the development of the first generation of the collector. This work will be carried over during this project to continue to improve this phase of each component.

5.4.1 Wear and Fatigue. Normal wear and fatique has been accounted for in the design of the sub system.

6.1 Accessibility for Maintenance and Servicing. No problems

are anticipated in this area.

6.1.1 Access for System Maintenance. The sub system will pose no problems for this requirement.

6.1.3 Draining and Filling of Liquids. Ease of draining and filling of liquids will be accomplished in the sub system.

6.1.4 Flushing of Liquid Sbusystems. The subsystem is designed to be easily flushed.

6.2 Installation, operation and Maintenance Manual. This will be addressed during the acceptance phase.

6.2.1 Installation Instructions. These will be addressed during the acceptance phase.

6.2.2 Maintenance and Operation Instructions. To be addressed during the acceptance phase.

6.2.3 Maintenance Plan. To be addressed during the acceptance phase

6.2.4 Replacement Parts. To be addressed during the acceptance phase.

6.3 Repair and Service Personnel. To be addressed during the acceptance phase.

6.3.1 Maintenance of H and HC Systems. To be addressed during the acceptance phase.

6.3.2 Maintenance of DHW System. To be addressed during the acceptance phase.

11.2.1 Chemical Corrosion. To be addressed during the accptance phase

11.2.2 Heat and Moisture. To be addressed during the acceptance phase.

11.3.1 Material Compatibility. To be addressed during the acceptance phase.

IV. TECHNICAL PERFORMANCE

The Development Plan, given in Section III summarizes the technical progress on the contract. A general summary of the work accomplished is given in the following sections.

A. Work Accomplished To Date

Significant progress has been made in the design of the key components (lens and receiver) and in the test and evaluation of the receiver. Progress in testing is given in Section IIIB., the Verification Plan. Progress of individual components are summarized as follows:

1. Concentrating Element - The lens die is currently being tooled by the subcontractor. Photographs of this new design, which will be used to extrude the lens described in the previous quarterly report, are given in Figure 3.

   Although extensive modeling of this lens design has already been done, the project team is looking forward to the receipt of this primary component, which will initiate the closing phases of the contract.

   The actual facet geometries were presented in the fifth monthly report. They are given again in Section IVD., the Date Package. The design is based on a 12" focal length and 8" radius of curvature, for reasons outlined in the First Quarterly Technical Report. The lens will utilize a total of 59 facets each efficiently designed to minimize any geometrical edge losses.

   When the first samples of the lens are received simultaneous testing of the lens and lens/receiver will be made. Focus intensity

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profiles similar to those presented in the last quarterly report will be run on each sample.

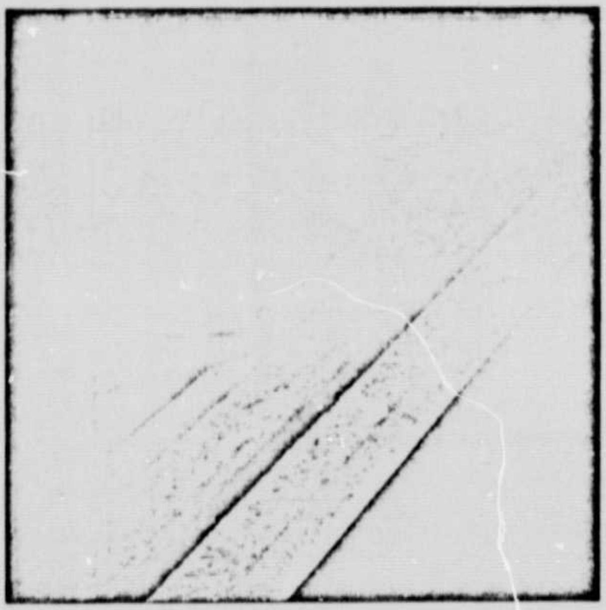
2. Receiver - In order to expedite the development of a cost - effective receiver, multiple alternatives were built and tested simultaneously. The three types were these:

a. Atmospheric receiver

b. Medium Vacuum receiver

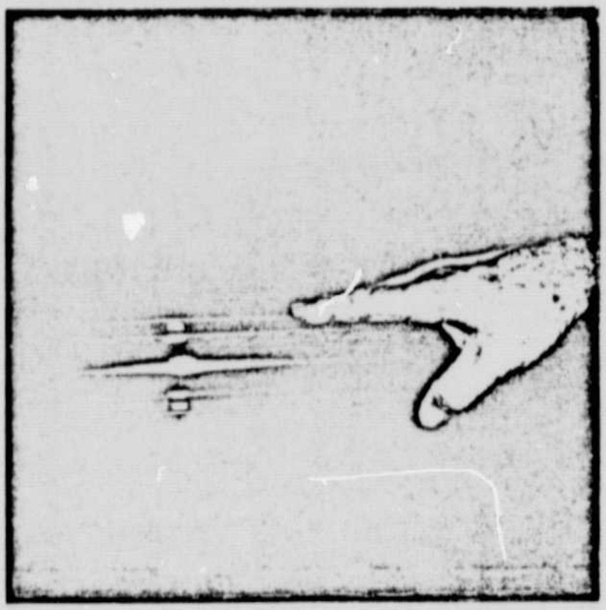
c. Deep Vacuum receiver (10^{-6} Torr)

The results of tests on these three receivers have indicated that all of the three alternatives as still under consideration, and that each has specific advantages that keep them in the running. Results of these tests are given on the following pages. Shown below is a photograph of the atmospheric receiver employing a teflon cover.



Deep Vacuum Receiver

Two major problems exist in hard vacuum receivers designs 1) outgasing of the absorber tube 2) the severe elongation of the absorber tube with respect to the glass jacket at elevated temperatures. The design approach used so far in this work utilizes a dewar sleeve composed of a double wall glass jacket with a hard vacuum in the annulus. Since glass has a lower thermal expansion coefficient than steel or copper, the difference due to elongation at elevated temperatures will not be as great. The seal between the two glass sleeves is not as great a problem in this configuration and the simple baking and annealing of the arrangement is possible. The inside layer of the dewar sleeve will be subjected to the high



The Deep Vacuum Receiver, using two layers of glass.

temperatures of the receiver. However, further heat flow across the annulus to the outer layer is eliminated by the hard vacuum. The glass jacket dewar sleeves are held in place by slit silicone O-rings or asbestos washers. Practical lengths of these dewar sleeves might be five feet, however 10 foot lengths are possible. The O.D. of the outer layer of the sleeve was about 2.0" while the I.D. of the inner layer was approximately 1.6". The thickness of the glass wall was .080". Quartz tubing was used in the prototype design because only simple fused joints were required due to the high strength and low thermal expansion coefficient of quartz. The absorber used with this dewar sleeve was a 1.125" O.D. copper tube, 1" nominal type L with a selective black chrome on nickel coating. Heat loss measurements were conducted on this receiver system. The method of testing was identical to that described in earlier monthly reports. Each test was made by preheating the absorber tube to more than 300°F for a period of 15 to 20 minutes. The heater was removed and the temperature was monitored each 30 seconds. The temperature decrease during each 30 second interval was then measured as a function of the difference in the temperature between the receiver tube and the ambient temperature. In all cases the ambient temperature was maintained as closely to 70°F as possible. From this data and the dimensions of the absorber a heat transfer coefficient can be determined for the receiver. However, the data has been left in original form since

comparison of the receiver thermal performances was the object of this study. Tests number 30 and 31, illustrate the data taken in this study and represent two separate but identical tests. At a receiver temperature of approximately 220^{o}F the temperature decrease per 30 seconds is approximately 3.3 degrees Farenheit. The pressure in the dewar sleeve was about 10^{-6} torr and a getter was flashed on the inside to serve as a vacuum indicator. Judging from the appearance of this getter the tubes did not appear to loose the vacuum prior to the tests and currently appear to be evacuated. Comparative data of two other tube designs utilizing a medium vacuum and no vacuum are given below.

Medium Vacuum Receiver

As in the previous design a 1.125" O.D. copper tube with a black chrome coating was used as the absorber. The selective coating minimizes the radiative losses from the absorber since the emissivity of the black chrome coating is about 0.12 for the infrared region of the spectrum. The convection losses as eliminated by reducing the annulus pressure between the absorber tube and a 4" O.D. glass jacket. This design utilizes a large annular spacing inorder to minimize the conduction across the gap. Typical operating pressures are between 1 micron and 1 torr and can be obtained with a simple roughing pump. After several years of service, the tube can be re-evacuated in the field if service is required. A silicone diaphragm provides the seal between the absorber tube and the glass jacket. This seal will withstand 600^{o}F temperatures and accommodate

the elongation of the copper tube while maintaining an excellent vacuum seal. The losses in this system should be slightly higher in this system than in the previous system, however there will be no need for baking to eliminate outgasing and a layer of glass will be eliminated.

Heat loss data was taken using the same procedure outlined earlier. The absorber was preheated to over 300^{0}F for a period of 15 to 20 minutes. The heater was removed and the temperature was monitored every 30 seconds. Test numbers 900020 to 900025, 900027 and 900029 are heat loss studies conducted at varying vacuums in the medium vacuum receiver. The figure comparing these measurements indicates that the effects of the medium vacuum are minimal at pressures above 5" of mercury. Theory indicates that based on the given glass tube and copper receiver dimensions the pressure for the suppression of natural convection at a receiver temperature of 300^{0}F is near 75 torr or about 3 inches of Hg. As illustrated in the graph a pressure of 5 inches of Hg has only minor influences on the heat loss while pressures less than 1 inch of mercury have a dramatic effect. The results indicate that the medium vacuum can be used effectively to reduce heat losses.

However, some problems still exist with the seal. Without a vacuum gauge, it is quite difficult to determine whether or not there are any leaks in the seal. Since a getter can not be flashed at these pressures, another visual indicator is necessary. One

possible indicator would be the application of a temperature sensitive material, temperature crayon or etc., on the outer surface of the glass. When the pressure increased to a point that the heat losses were very high across the annulus the indicator would show the loss in vacuum by responding to the temperature change.

Atmospheric Receiver

A teflon window can be used over an insulated tube to reduce heat losses as illustrated in the figures in graphs of test numbers 900026 and 900028. One configuration utilizes a single cover, test 900026, while the other utilizes a double teflon cover. The tube is selectively coated with black chrome or nickel to reduce the radiative losses and conduction-convection losses are reduced by placing insulation along three sides of the receiver. Convection losses on the fourth side, the top, are minimized by the application of the teflon film at the proper spacing above the receiver tube. Since the index of refraction of teflon is about 1.35, the transmission through this film can be as high as 94 to 95%.

The heat loss test procedures were identical with those of the previously described tests. The tests indicate that the heat losses from a tube in the above describe condition with a single teflon cover is nearly the same as the losses the medium vacuum receiver. The addition of the second teflon cover does not appear to make a significant improvement in reducing the losses at the temperatures of these tests. This design is significantly less expensive than the previous design and could be extremely effective as a receiver tube assembly for use with lenses. A problem

which has occured in this design is the deposition of a milky white film on the teflon at stagnation temperatures about 500^{O}F. Outgasing of the binder in the insulation is believed to be the cause or origin of the deposited film. A new low-binder insulation has been tested and does not produce the outgasing layer to the extent that the original insulation did. Tests are currently being conducted to measure the transmission of the teflon layer over long periods of time at elevated insulation temperatures. An alternate approach being investigated is baking or cooking the insulation at temperatures of 800^{O}F in order to outgas the binder. Performance tests of efficiency will be made as soon as samples of the new lens are available.

HEAT LOSS TESTS

Test No.	Description (All tests - 8' long, 1.125"O.D.,type L, copper tube)
900001	Plain copper tube, horizontal
900002	Plain copper tube, 30^{O} incline
900003	Plain copper tube, horizontal, glass jacket, 2"O.D., 0.100" wall
900004	Plain copper tube, 30^{O} incline, glass jacket, 2"O.D., 0.100" wall
900005	Black chrome/Nickel coating, horizontal
900006	BC/Ni coating, 30^{O} incline
900007	BC/Ni coating, horizontal, glass jacket, 2"O.D., 0.100" wall
900009	BC/Ni coating, horizontal, lower half in insulation
900020	BC/Ni coating, horizontal, glass jacket, 4"O.D., 0.100" wall Pressure - 1" Hg in annulus
900021	BC/Ni coating, horizontal, glass jacket, 4"O.D., 0.100" wall Pressure - 5" Hg in annulus
900022	BC/Ni coating, horizontal, glass jacket, 4"O.D., 0.100" wall Pressure - 10" Hg in annulus

900023	BC/Ni coating, horizontal, glass jacekt, 4"O.D., 0.100" wall Pressure - 15" Hg in annulus
900024	BC/Ni coating, horizontal, glass jacket, 4"O.D., o.100" wall Pressure - 20" Hg in annulus
900025	BC/Ni coating, horizontal, glass jacket, 4"O.D., 0.100" wall Pressure - 25" Hg in annulus
900026	BC/Ni coating, horizontal, embedded in insulation 2" thick 1 teflon cover (see diagram in graph)
900027	BC/Ni coating, horizontal, glass jacket, 4"O.D., 0.100" wall Pressure 0" Hg in annulus
900028	BC/Ni coating, horizontal, embedded in insulation 2" thick, 2 teflon covers (see diagram in graph)
900029	BC/Ni coating, horizontal, glass jacket, 4"O.D., 0.100" wall No vacuum in annulus
900030	BC/Ni coating, horizontal, dewar jacket, 2"O.D., 1.6" I.D., Vacuum 10^{-6} torr, 2-4 ft. pcs., Run #1
900031	BC/Ni coating, horizontal dewar jacket, 2"O.D., 1.6" I.D., Vacuum 10^{-6} torr, 2-4 ft. pcs. Run #2

Discussion:

Heat loss measurements of all three designs indicate nearly identical performances by each of the designs. The time period acquired to cool from 250°F to 150°F at an ambient temperature of 70°F is listed below for each of the previously documented tests.

Test No.	($^{\circ}$F-$^{\circ}$F) Temperature Range	(minutes) Time Period
900001	253.3 - 154.3	6
900002	250.7 - 152.5	6.5
900003	251.8 - 150.8	13
900004	251.5 - 150.8	13
900005	250.1 - 149.6	7
900006	254.2 - 154.1	6.5
900007	252.2 - 152.2	12.5

900008	253.2 - 153.9	12.5
900009	253.3 - 151.3	12.5
900020	252.3 - 153.2	21.5
900021	251.8 - 151.3	17
900022	251.1 - 152.1	14
900023	250.9 - 150.5	13.5
900024	249.0 - 148.6	13.5
900025	250.9 - 149.8	12.5
900026	250.7 - 150.4	22
900027	250.8 - 149.6	24.5
900028	249.6 - 148.8	24
900029	252.4 - 152.6	12
900030	251.1 - 150.5	23
900031	250.4 - 151.1	23

Test # 900027, # 900026, and # 900030 compare the three receiver designs, the medium vacuum, the atmospheric receiver, and the deep vacuum receiver, respectively. The corresponding time constants are 24.5 minutes, 22 minutes and 23 minutes. The 22 minute time constant of the atmospheric receiver was the most surprising indicating almost a doubling of the time constant by the simple application of a convection suppressing Teflon cover. The partial vacuum results are quite close to the theoretical projections and therefore afford little surprise in performance. The relatively poor performance of the deep vacuum receiver was quite surprising. One possible reason for this poor performance was the absence of a selective surface on the inner layer of glass. The inner layer of the dewar jacket was subjected to the

elevated temperatures and this surface became the radiator. Since the emissivity of glass is so high much of the energy was radiated to the outer surface or layer of glass. Another significant loss must have occured at the junction of the two-4 foot dewar sleeves. The application of an infrared mirror is being investigated at this time.

From the above results one might conclude that the simple atmospheric receiver could be the most efficient design. This design can be used with lenses with success due to the relatively small aperature width required. However, it does require the use of a swivel joint to accommodate the tracking of the collector. As a result improved swivel joints are the subject of current studies and designs utilizing different seals are being investigated.

3. Attitude Controller - The tracking control has been improved considerably since the last report.

In the last few weeks an unsuspected failure mode has become evident in the new design for the attitude controller. This failure mode only recently occurred often enough to see that there was a problem or that there could be a problem. The failure mode is suspected to occur when the tracker motor is given power to drive both East and West at the same time. If this should occur it is possible for a current surge to damage one of the control triacs.

Three tracker controls in the test installation were suspected to have been damaged by this failure mode. The triac manufacturer tested the triacs and saw evidence that a current surge did occur.

Future tracker boards will be modified to eliminate this possible problem by adding a second resistor in series with the motor run capacitor.

Any additions to the new tracker design will have adequate surge protection.

Additional improvements are described in the Forecast of Work Section IVB. These improvements may include:

a. Addition of a fail-safe control, that will cause the collectors to off-focus when flow stops, thereby avoiding stagnation pressures and temperatures.

b. Continued testing of the printed circuit board, possible additional work on the triacs that turn the motor on and off.

c. Addition of a sheer pin to the motor drive shaft, to protect the system from lock-up of tracking driver and subsequent motor failure.

d. Continued cost reduction efforts on all components.

4. Casing Element - The outgassing of previous insulation materials has been rectified by using a special Ownes-Corning high temperature insulation. On-going tests of the atmospheric receiver will employ this new low-binder insulation. The use of a teflon cover over the receiver may eliminate the need for housing side-wall insulation.

Additional improvements have been made in the weather stripping used at the lens/casing juncture, and in the weatherability of the casing material.

Minor rust problems have been encountered in severe marine environments, and extra cadmium and zinc plating have been added to problem areas.

Considerable testing of casing components have been performed to check weatherability. Figure 4 illustrates a salt-spray simulation test, conducted under controlled conditions over a period of several weeks.

The possibility of a molded plastic housing was explored with a large plastic fabricator. The cost/benefit of such an approach indicates that it may not be practical for any of the present atmospheric receiver.

The use of light weight sheet metal (24-26 gauge) with reinforcing brackets is being considered, both for the atmospheric and evacuated models.

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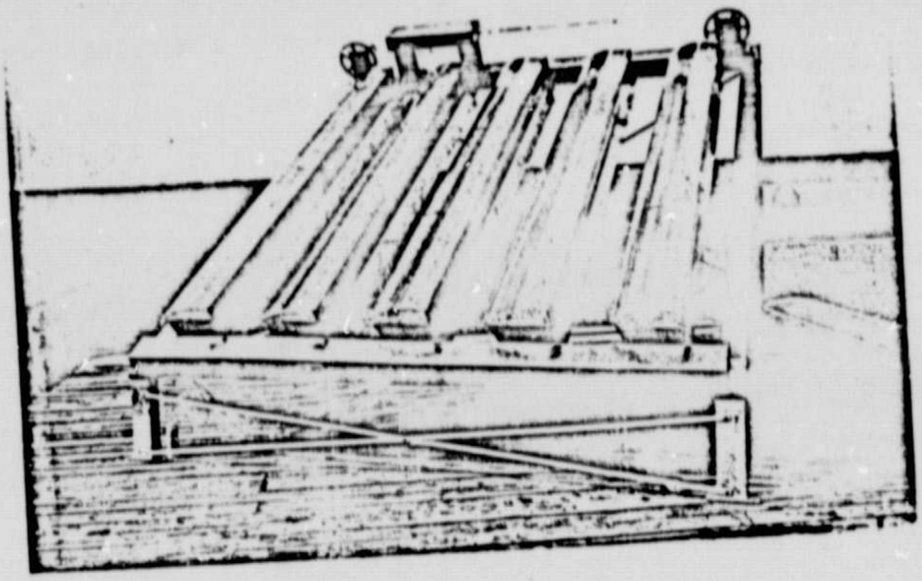

Photo of Northrup Test Area

Figure 4

Salt Spray tests conducted to determine rust problems on end panels.

5. Manifold Element - Several types of swivels are being tested for use with the atmospheric receiver, and designs are being made for large bearings to be used with the evacuated (stationary) receivers.

Significant design improvements have been made on the swivel fittings. An additional "O"-ring has been added and the surface smoothness of the "O"-ring chamber has been improved considerably.

New "snap-connect" fittings are being tested for possible improvements for ease of alignment in the field, and longer seal life.

Large bearings, including low-cost teflon units, are under consideration for use with the evacuated receivers. In the event that an evacuated or stationary receiver is used, the casing will revolve around the receiver element. The center of gravity and wind loading of this type casing will present some design consideration that are currently resolved in the atmospheric receiver.

More accurate copper manifold connections may be attained with the use of a new device, that drills a hole in the manifold, then pulls a "lip" out of the hole, effectively creating a collar around each hole. The use of this device is being considered.

B. Forecast of Work

The work forecasted for each component category is considered in the Development Plan. Specific action to be taken is outlined below.

1. Lens - The fabrication of the lens and subsequent delivery from the manufacturer will enable the design and test personnel to confirm their thinking on the improved lens. Considerable test efforts are anticipated to commence in the third quarter of the project. Should redesign be necessary, it can be accomplished very quickly and simultaneous retooling may be possible.

2. Receiver - By the third quarter, the decision on the receiver tube should be made. While fairly conclusive data is in on the performance on the three alternatives, it is still too early to drop any of them. Tests will continue to confirm the empirical information on the three types. When sample lens become available for testing, the following modes will be checked for relative performance:

Receiver / Lens	Old Atmospheric	New Atmospheric	Medium Vacuum	Deep Vacuum
Old Lens	1	3	5	7
New Lens	2	4	6	8

The relative merits of each configuration will be checked according to the following formula:

$$\text{Cost Effectiveness} = \frac{\text{\% increase in energy collected}}{\text{\% increase in cost}}$$

Increase in cost will take into considerations the discrete cost of each component, plus the imputed cost differentials associated

with casing, tracking, etc.

All tests will be conducted at Northrup's test facilities The most promising configuration will be sent out for independent test agency certification.

3. Casing - The collector housing for atmospheric receiver has enjoyed several design improvements during the course of the project. Additional efforts will be made to improve the weather sealing and lower the cost of the housing.

Should an evacuated receiver prove more cost effective than an atmospheric receiver, a new casing will be developed to accomodate the receiver in a stationary configuration. Considerable testing would remain to be performed on such a housing.

4. Attitude Controller - As mentioned earlier, several improvements will be undertaken to improve the durability and lower the cost of the tracker. These improvements, again, are these:

a) sheer pin on the drive motor

b) inclusion of relays to further protect the motor on-off triacs

c) option to off-focus collectors during periods of stagnation

d) continued study of a synchronous motor or internal clock to keep the tracker "vaguely right" during partly cloudy condition, when tracking is normally interrupted by clouds.

C. Problems Encountered

The attitude controller has had problems as delineated in IVA. These problems have been corrected as previously indicated.

Improvements in the swivels used with the atmospheric receiver have resulted from recognition of problems encountered with the "O" ring grooves and overall design logic.

The swivel fitting has been improved to prolong the life of the swivel. Two solutions to the problem of early failure were selected: First, the Northrup designed swivel was changed to effect improvements; second, a commercially available swivel was tested and selected. We now have two satisfactory solutions for the swivel problem and we will move forward with both of these solutions unless one of the solutions proves to be superior. In this case, the superior solution will be chosen and the inferior solution dropped.

In regard to the Northrup designed swivel; the causes for early failure were identified and improvements made to remove each cause for failure. The surface finish of the sealing surface was improved by developing manufacturing techniques which provided a better honed finish to the bore. The set screw which closes a bearing insertion hole was sealed; this eliminated a leak path which existed when one seal failed. The sharp edges which are internal to the swivel were rounded to assure that the seal was not cut or damaged during assembly.

In regard to the commercially available swivel, several products were examined and trade studies were completed. The final choice was a product made by Snap-Tite, Incorporated, Union City Pennsylvania. The product is known as BPHC 4-4F EPR, and is made from materials which are satisfactory for the Northrup Concentrating Collector.

The materials are: brass for the body, stainless steel for the locking balls and spring, and ethylene propylene rubber for the seal.

Both the improved Northrup swivel and the Snap-Tite swivel are demonstrating improved performance over the previous configuration.

Resistance to corrosion has been improved on the end plates and pivot shafts of the atmospheric receiver housing. This improvement was determined to be necessary when equipment exposed to heavy maritime environment oxidized in limited areas.

Tests consisting of exposing the test parts to salt (Na Cl) and water (H_2O) were run. The tests provided data regarding the resistance to corrosion of several combinations of platings and coatings.

The result of the investigation and testing resulted in three improvements. First, a weld head was added to the pivot shaft to eliminate a cavity where water and other contaminants were collecting and producing corrosion. Second, the Cadmium plating thickness on the pivot shaft weldment was increased from .0002 inch to .0005 inch. Third, a coating of a corrosion resistant paint; "Cold-Galv" which is very high in zinc dust content and conforms to specifications MIL-P-26915A and MIL-T-26433 was selected and applied.

In summary, we identified and solved a problem relating to corrosion on the end-plates and pivot shaft assemblies. The problem was solved by adding a weld, increasing the plating thickness, and adding a protective coating.

The Solar Cell Assembly was improved by providing a better mounting position, sealing the housing that contains the Solar Cells, and adding a desiccant material inside the Solar Cell Assembly to eliminate residual moisture.

The better mounting was accomplished by changing the length of the shaft which positions the Solar Cell Assembly. The length was changed from 9½ inches to 13¼ inches. This eliminated certain shadow patterns which fell on the Solar Cell Assembly in a limited number of configurations.

The sealing of the Solar Cell Assembly was accomplished with a Silicone Rubber Compound manufactured by General Electric and known as RTV 103 Black. All leak paths for moisture were sealed, including the opening where the electrical wires enter the assembly.

The residual moisture which remains in the Solar Cell Assembly after sealing was eliminated by inserting a small package of silica gel in the base of the assembly. This desiccant will eliminate the fogging and sweating on the inside surface of the Solar Cell Assembly that would exist in the sealed assembly if the moisture were not removed.

These three improvements to the Solar Cell Assembly have been incorporated into current production models.

A shear pin to protect the motor in the tracking system is being studied. The purpose of this study is to develop a device which will disconnect the motor from the drive screw if an overload condition of 40 to 60 inch-pounds should exist.

To-date the investigation is not complete, but plans have been made to perform trade studies on roll pins vs. solid pins, notched pins vs. un-notched pins, single shear application vs. double shear application, and brass vs. steel vs. aluminum.

The electronic circuit board in the Northrup Solar Tracking System was improved. One improvement consisted of changing the resistance value of a resistor from 4 ohms to 8 ohms. This change limited a current flow and reduced significantly a stress that was causing failures. The other change was the adding of a conformal coating to both the upper and lower sides of the circuit board. This conformal coating is manufactured by Dow Corning and is known as DC3140. The coating provides three advantages: 1) Sealing all board components and the board itself from moisture, 2) Providing electrical insulation protection to previously uninsulated circuits. This added insulation prevents an undesired circuit (short circuit) when a metal chip or other random conductor impended on the "printed circuit" on the lower side of the board. These short circuits have caused failures, 3) Providing electrical insulation to prevent undesirable electrical discharge of capacitor during assembly of the tracking package.

D. Data Package

The raw data on the heat loss tests conducted on the three receiver types is available upon request.

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